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# FleCSPH : A New SPH Code Based on FleCSI Framework

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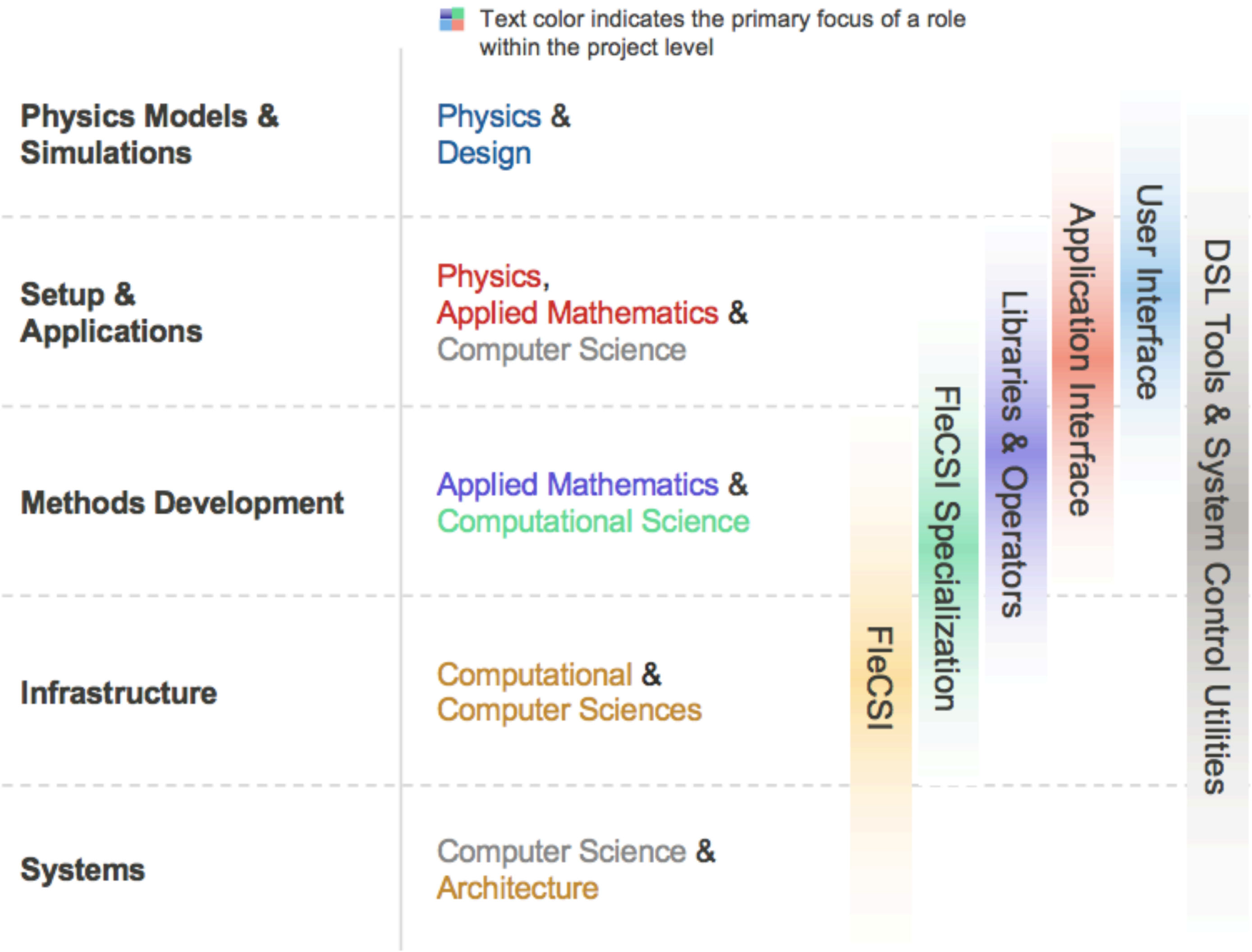
# LA-RISTRA project

- **Provide flexible computational infrastructures to solve multi-physics problems**
- **Current main projects involve**
  - FleCSI
  - FleCSALE
  - FleCSPH
  - More in future



Text color indicates the primary focus of a role within the project level

| | |
|---|---|
| Physics Models & Simulations | Physics & Design |
| Setup & Applications | Physics, Applied Mathematics & Computer Science |
| Methods Development | Applied Mathematics & Computational Science |
| Infrastructure | Computational & Computer Sciences |
| Systems | Computer Science & Architecture |

FleCSI

FleCSI Specialization

Libraries & Operators

Application Interface

User Interface

DSL Tools & System Control Utilities

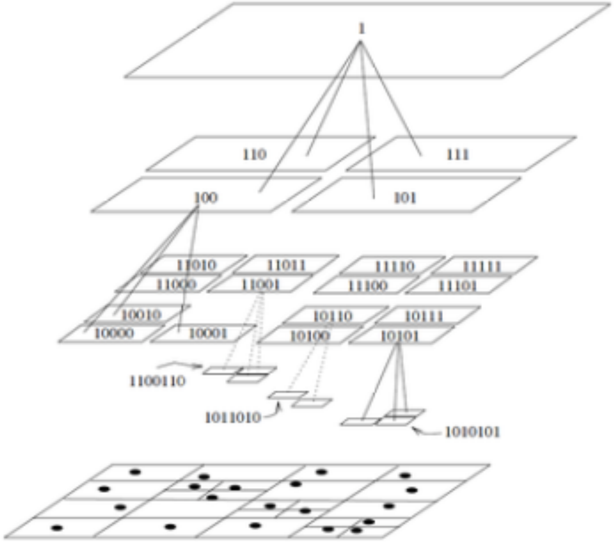
# What is the FleCSI??

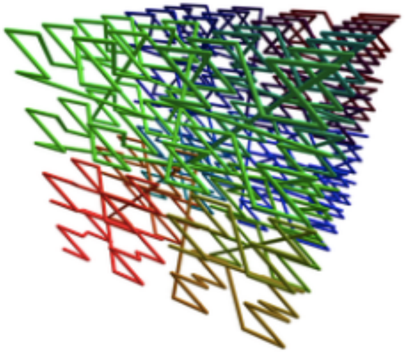
# FleCSI

- **FleCSI is a C++ programming system for developing multi-physics simulation codes**
- **Runtime abstraction layer**
  - High-level user interface, mid-level static specialization etc..
- **Programming model**
  - Control, execution, and data models
- **Useful data structure support**
  - Mesh, N-Tree, and KD-Tree

# FleCSI : Tree Data Structures

- **Tree topology**
  - Support n-tree (also hashed n-tree)
  - Constant-time neighbor look-up
  - Morton ordering
  - Refinement and coarsening
  - Applications: SPH, N-body, AMR, Complex Flows, Monte Carlo, Molecular Dynamics

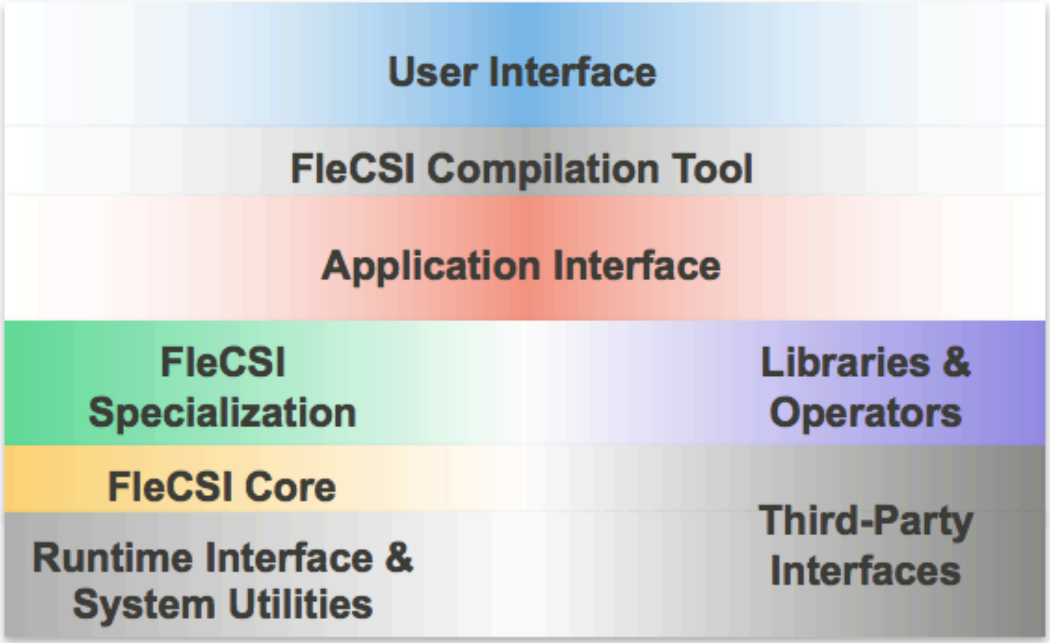




# FleCSI : Where does it sit in the software stack?

Provides high-level, domain-specific
interface that requires syntax
and semantics
not available in C++

Data & Execution Model
Implementations



User Interface

FleCSI Compilation Tool

Application Interface

FleCSI Specialization

Libraries & Operators

FleCSI Core

Runtime Interface & System Utilities

Third-Party Interfaces

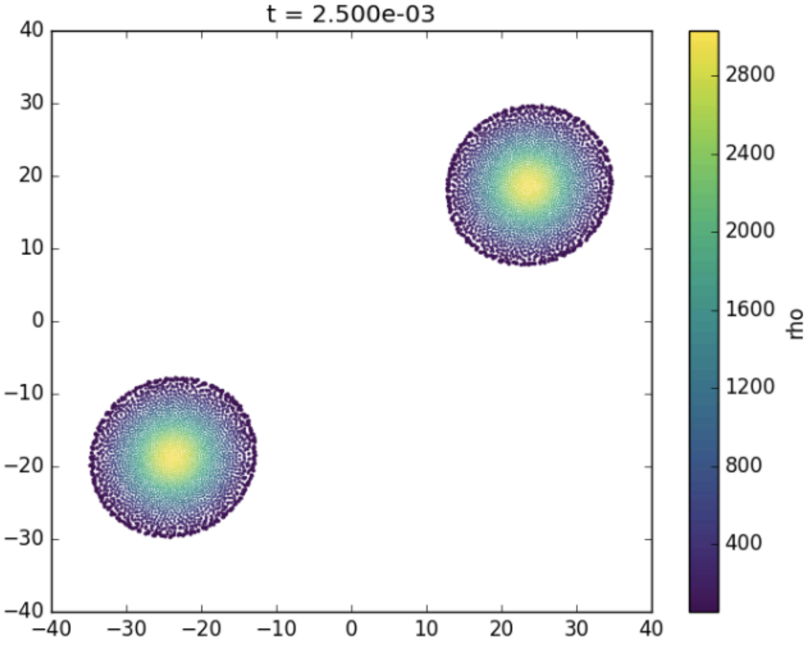
# What is the FleCSPH??

# FleCSPH

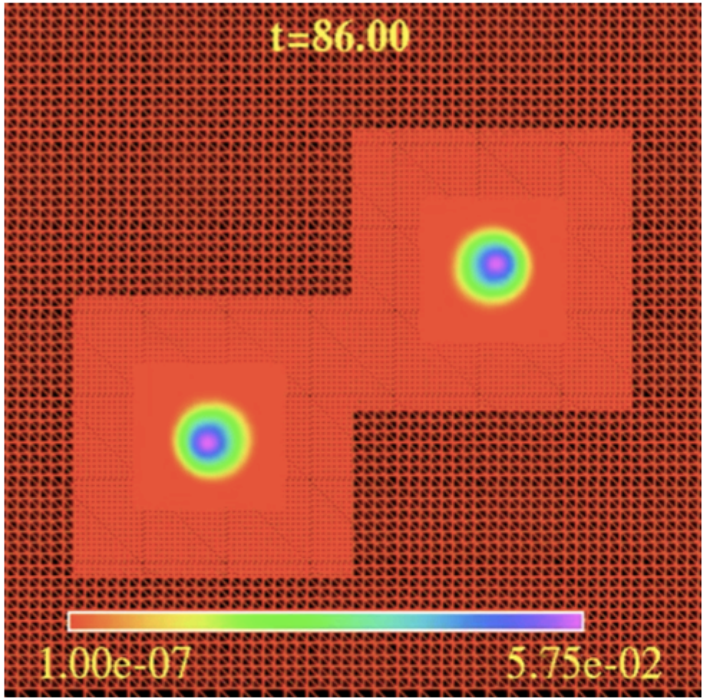
- **FleCSPH is an implementation of smoothed particle hydrodynamics (SPH) based on the FleCSI frame work**
- **Started to develop April 2017**
- **Julien Loiseau and Hyun Lim are main developers**
- **Solves Lagrangian conservation equations for mass, energy and momentum of an ideal fluid with Newtonian gravity**

# Why SPH?

- Exactly conserves mass, linear & angular momentum, and energy
- Perfectly handle vacuum, deformation



- Artificial atmosphere required



# Why SPH?

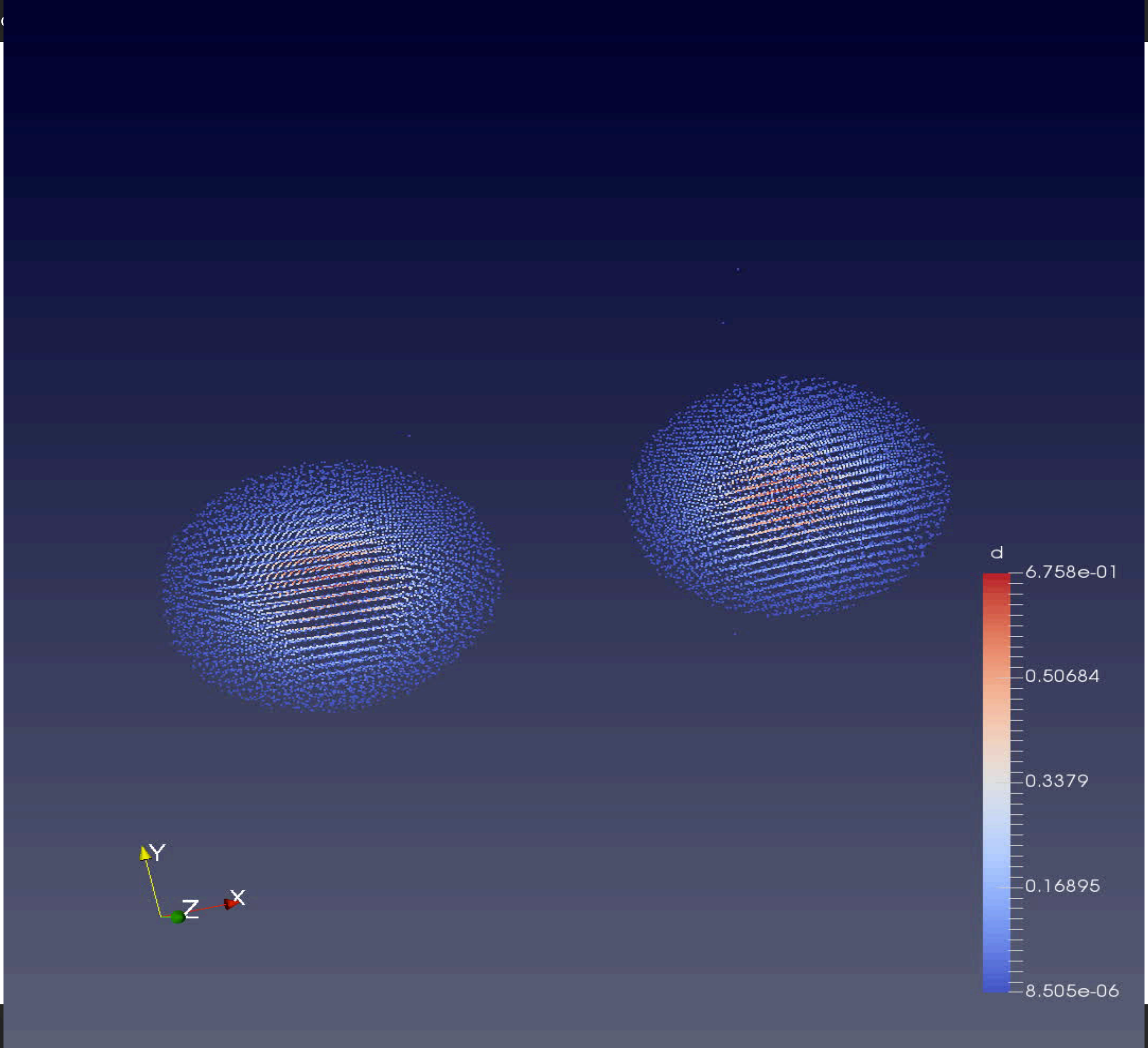
- **SPH is interesting method to test tree data structure**
- **Suitable method for combining with FleCSI infrastructure**
- **Perfect test case for complicated problem for Exascale computing**
- **Has a lot of testable applications:**
  - Space filling curve
  - Neighbor searching
  - Different tree traversal and sorting algorithms

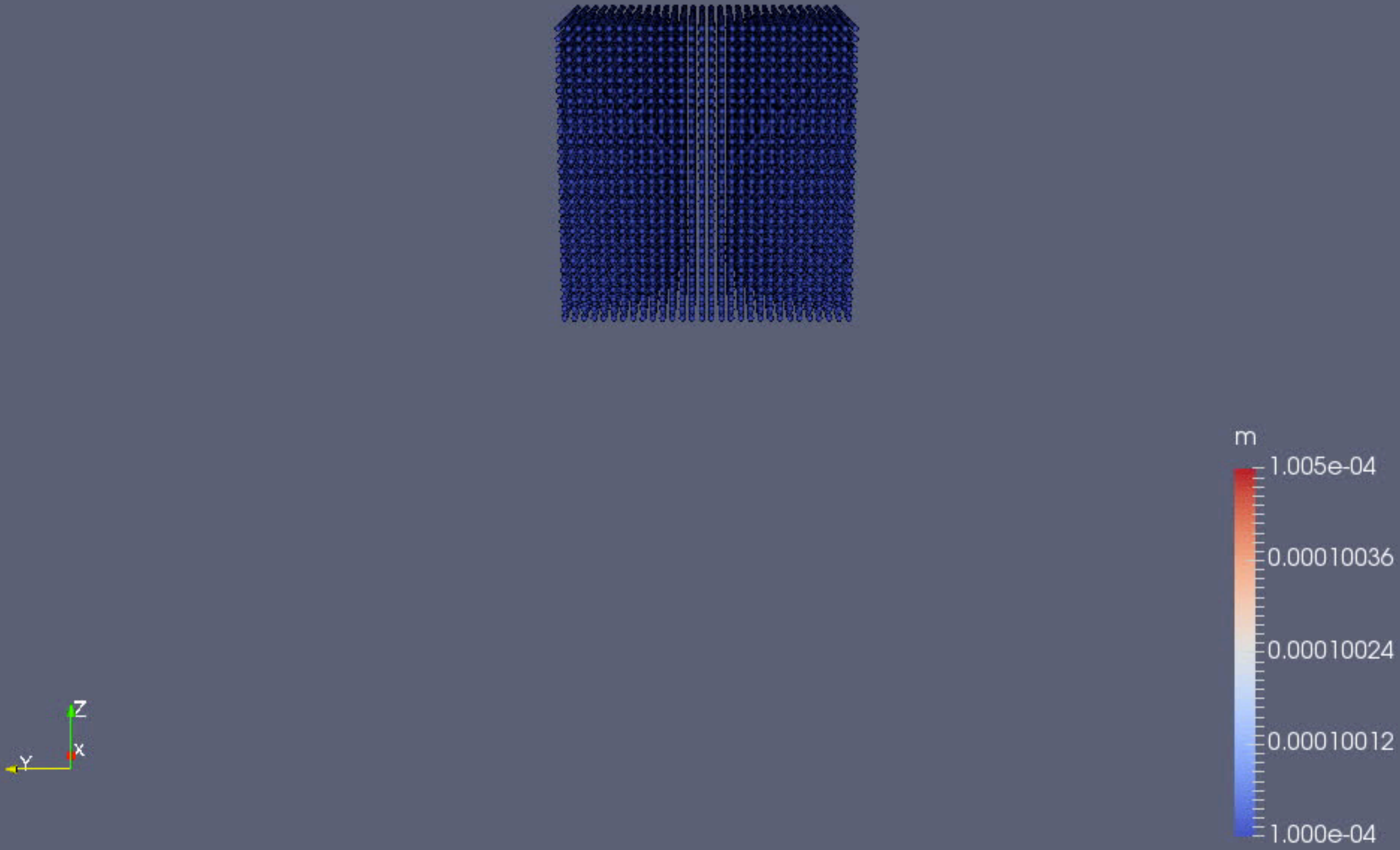
# FleCSPH : Current Development

- **FleCSPH has capabilities:**
  - Cubic spline kernel approximation
  - Hydrodynamics with Newtonian gravity
  - I/O with h5part
  - Parallel and distributed memory shared scheme
  - Parallel jobs are executed through MPI and Legion

# FleCSPH : Preliminary Results

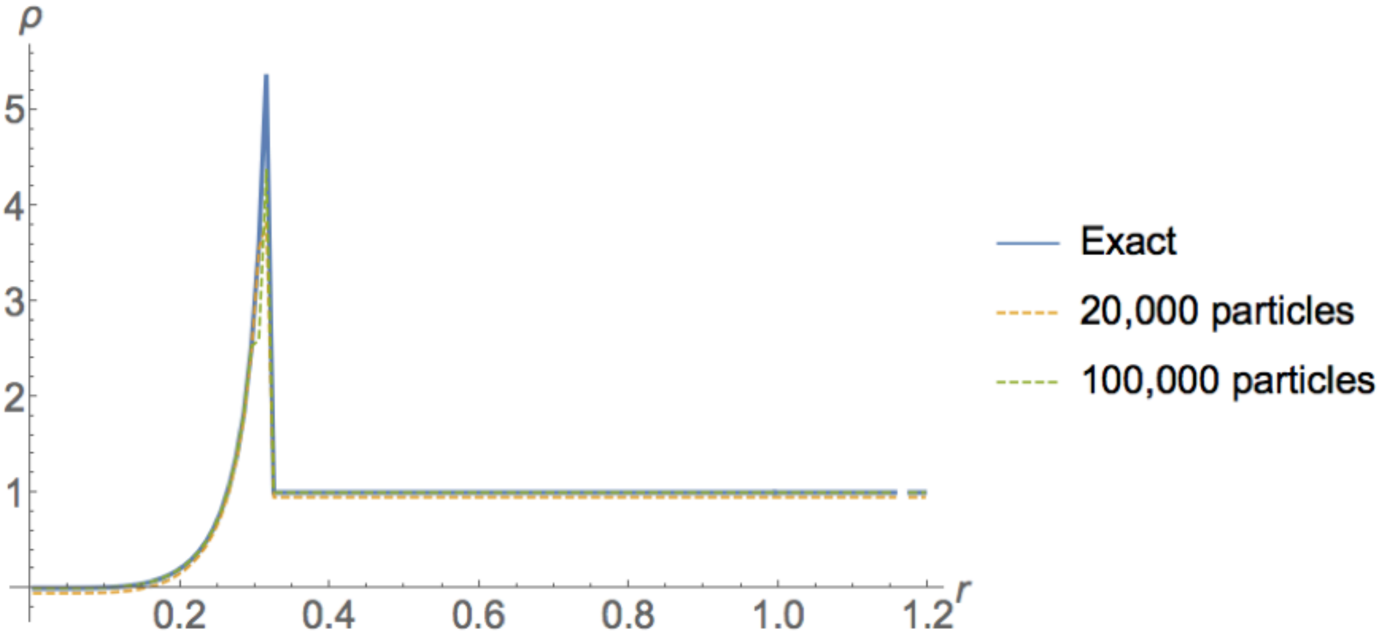
- **Currently, we tested several different problems:**
  - 1D Sod shock tube
  - 2D Sedov blast wave
  - 3D Fluid problem : Water cube drop
  - 3D Compact binary objects
    - Double white dwarfs
    - Binary Neutron Stars
  - Working on more astrophysical problems…


d
6.758e-01
0.50684
0.3379
0.16895
8.505e-06
Y
Z
X

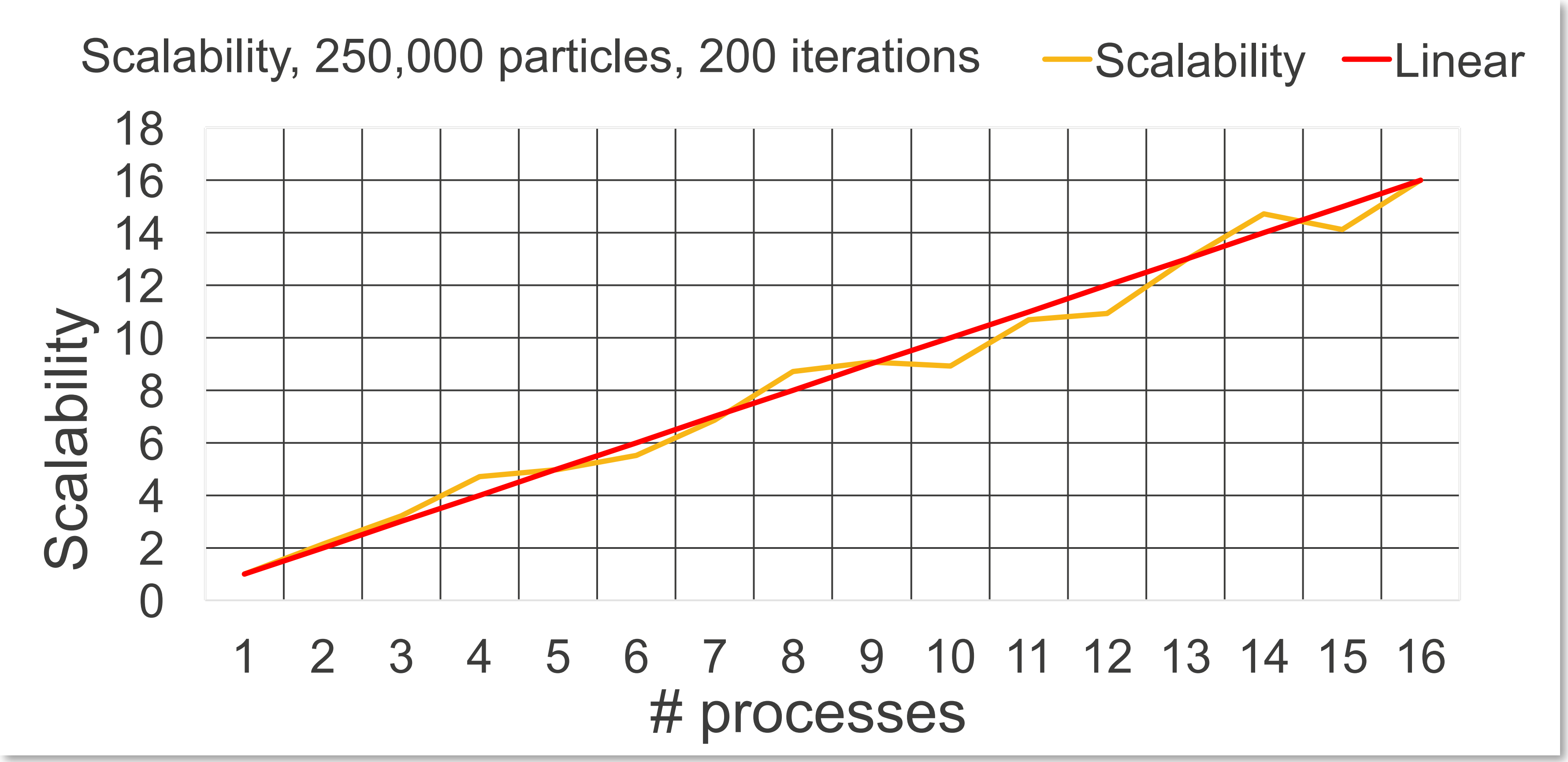

m
1.005e-04
0.00010036
0.00010024
0.00010012
1.000e-04
Z
X
Y

# Performance Results

Density plot for comparison Sedov blast wave result



# Performance Results



# Conclusion and Future Works

- **FleCSPH is still developing!!**
- **Need to put different functionalities:**
  - Different types of EOS (includes tabulated), more microphysics
  - Nuclear network
  - ID generator that is suitable FleCSPH
  - Different smoothing kernels
  - Add gravitational wave radiation reaction
  - And more…

# Conclusion and Future Works

- **Add complete framework into FleCSI:**
  - Add different space filling curve : Hilbert, Peano, Gosper
  - More task-based runtime model
  - More optimized and multi-purpose tree code

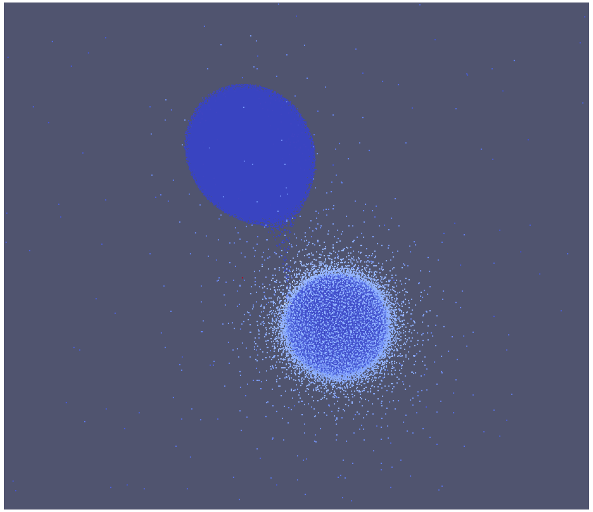
# To use FleCSPH.....

- Go to our github page

https://github.com/laristra/flecsph

- Follow the instruction and enjoy!!

- If you have any questions, please contact Hyun Lim and Julien Loiseau



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ngiyabonga
Баярлалаа
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teşekkür ederim
спасибо
mersi
kia ora
barka
welalin
tack
mahalo
tapadh leat
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misaotra
paldies
grazzi
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matondo
gracias
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nanni
nandri
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bayarlalaa
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তোমাকে ধন্যবাদ
감사합니다
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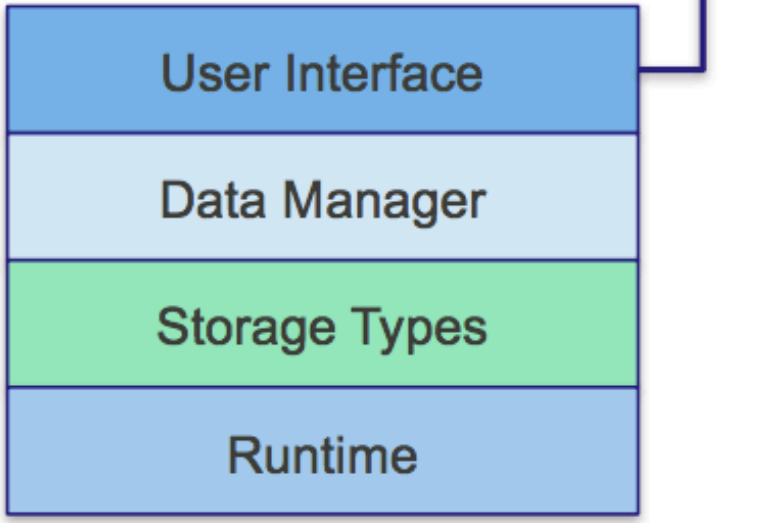
merci

# Back Up

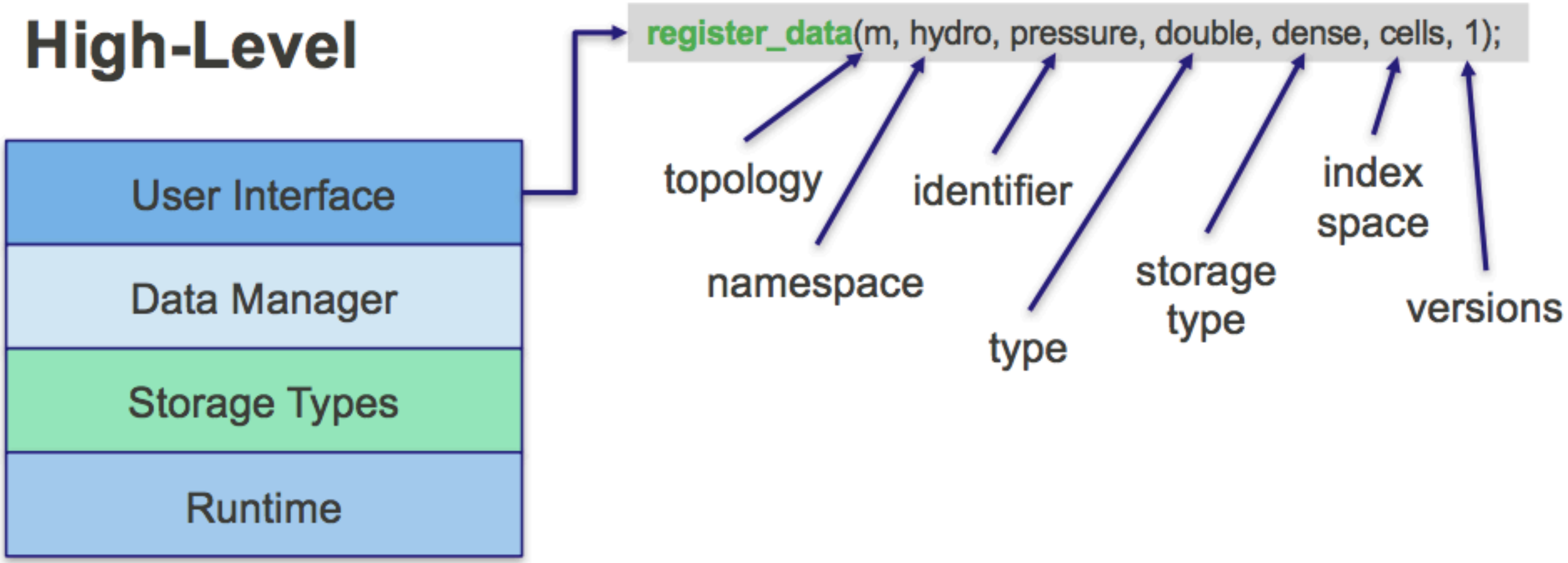
# FleCSI : Data Interface?

## High-Level



```
register_data(m, hydro, pressure, double, dense, cells, 1);
```

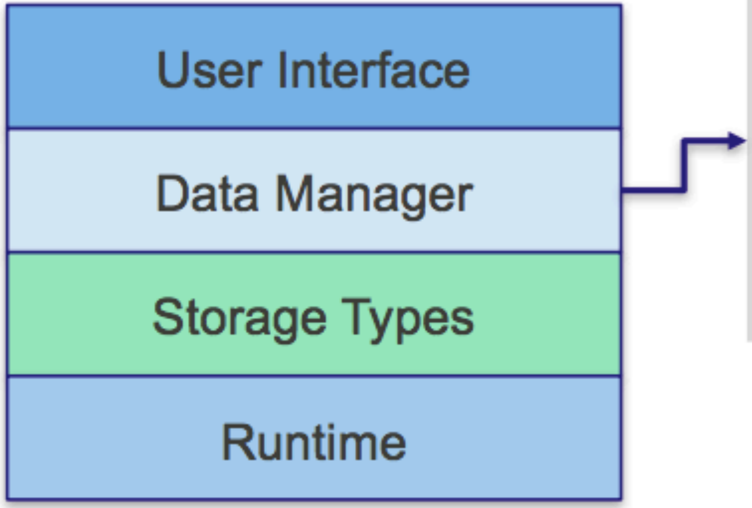
# FleCSI : Data Interface?



```
register_data(m, hydro, pressure, double, dense, cells, 1);
```

# FleCSI : Data Interface?

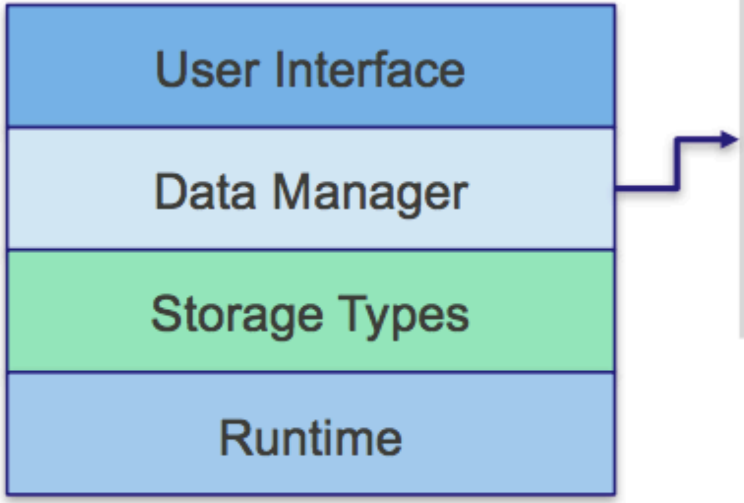
## Direct Interface



```
template<size_t ST, typename T, size_t NS,
typename ... Args>
decltype(auto) register_data(
data_client_t & data_client,
const const_string_t & key,
size_t versions=1,
Args && ... args)
```

# FleCSI : Data Interface?

## Direct Interface



```
template<size_t ST, typename T, size_t NS,
typename ... Args>
decltype(auto) register_data(
data_client_t & data_client,
const const_string_t & key,
size_t versions=1,
Args && ... args)
```

storage type

type

namespace

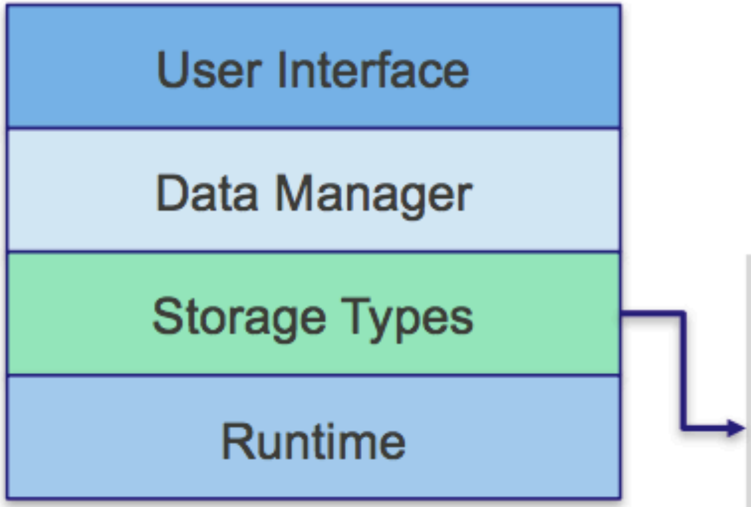
topology

identifier

versions

# FleCSI : Data Interface?

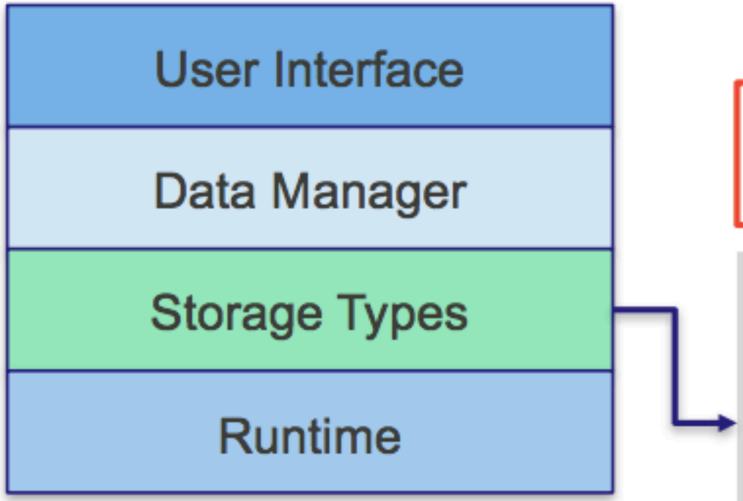
## Low-Level



```
template<typename T, size_t NS, typename ... Args>
static handle_t<T> register_data(
   data_client_t & data_client,
data_store_t & data_store, const const_string_t &
key, size_t versions, size_t index_space, Args && ...
args)
```

# FleCSI : Data Interface?

## Low-Level

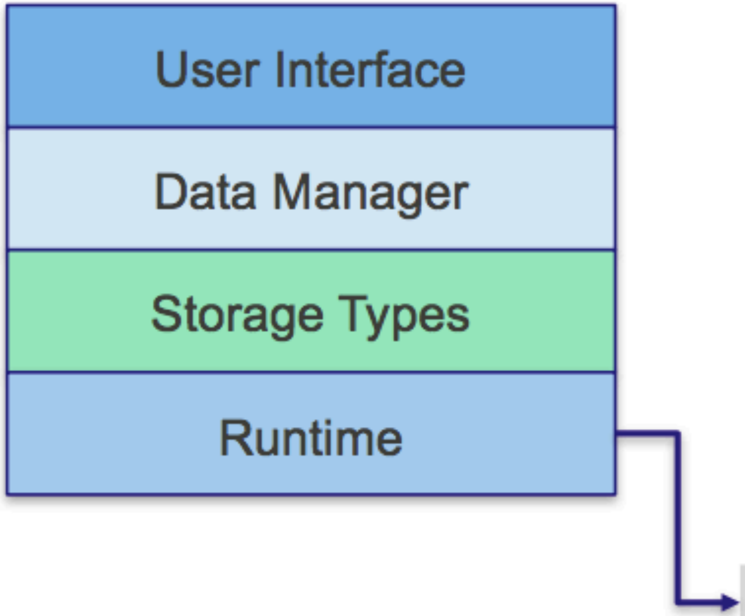


Mapped to specific storage type

```
template<typename T, size_t NS, typename ... Args>
static handle_t<T> register_data(
   data_client_t & data_client,
data_store_t & data_store, const const_string_t &
key, size_t versions, size_t index_space, Args && ...
args)
```

# FleCSI : Data Interface?

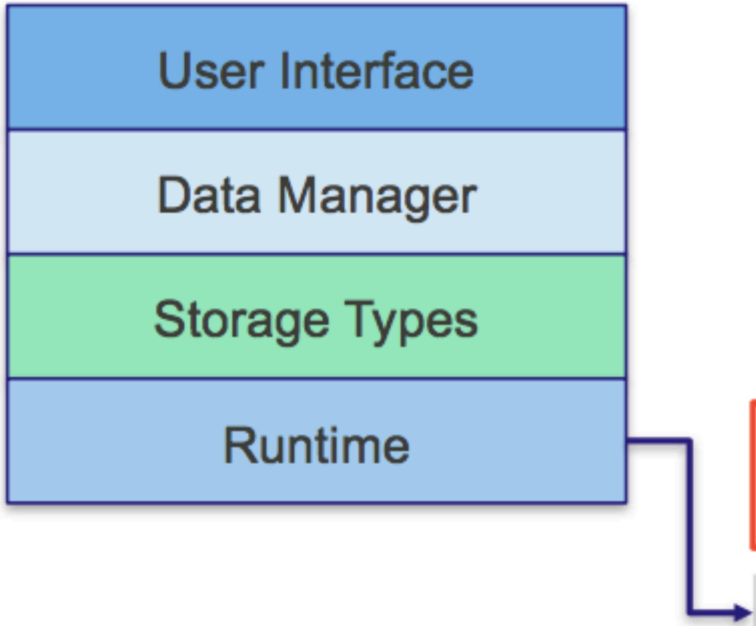
## Backend



```
FieldSpace fs = runtime->create_field_space(ctx);
```

# FleCSI : Data Interface?

## Backend



Storage type uses Legion runtime to create appropriate field space(s)

```
FieldSpace fs = runtime->create_field_space(ctx);
```